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ON THE POSSIBILITY OF UTILIZING GEOMAGNETIC STORMS FOR THE STUDY OF THE EARTH'S ELECTRIC CHARACTERISTICS

by

M. B. Kokhberg

(USSR)

8 MARCH 1966

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FOR THE STUDY OF THE EARTH'S ELECTRIC

CHARACTERISTICS

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SUMMARY

The magnetic storms being a powerful and clearly expressed event
in the Earth's electromagnetic field, the possibility is explored of their
utilization for the practical determination of the Earth's sub-surface geo-
electric characteristics by the method of magneto-telluric sounding.

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At present the magneto-telluric sounding curves (m.t.s.) [1 — 3],
by which the depth parameters of the geoelectric profile are determined,
are plotted by way of processing the variations of the Earth's natural
field, which, generally speaking, have a distinct nature. As will be shown
below, a series of important parameters of the sub-surface structure of the
Earth may be obtained by processing the concomitant readings of electric
and magnetic components of SC magnetic storms' initial phase. The electro-
magnetic fields of such storms, observed on the ground, are naturally con-
nected with the distribution of its conductance in depth. The field compo-
nents reflect the conducting Earth's electromagnetic field in the making.

The rapid field accretion and the sharply-expressed initial stage
of the porcess that may last in the magnetic storms two hours and more,
constitute the characteristic peculiarity of the abrupt onset of bay-like
perturbations as well as of magnetic storms. The complex character of the

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"tail" part of the process hinders the application of the standard analysis approach, and more particularly of the Fourier spectral decomposition utilized in the m.t.s. method.

The procedure applied in [4] allows to materialize the quenching of the tail, or residual part of the process and to extract the information of interest to us concerning the geoelectric profile from its more clearly expressed initial phase. At the appropriate processing of such a nonstationary process, information on the sub-surface structure may be obtained from the initial time interval, substantially smaller than at harmonic analysis of the readings, in particular of daily variations of the Earth's natural electromagnetic field.

The sharp nonstationary perturbation of the electromagnetic field registered in the Ashkhabad region on 4 December 1962 by V.G.Dubrovskiy of the Turkm.SSR Academy of Sciences, is plotted in Fig.1. This is one of the most favorable cases whereby there is a clearly-marked entry of both, the electric and the magnetic fields. While the horizontal componnent of the magnetic field, H_x reaches a specific level, holding at it for some two
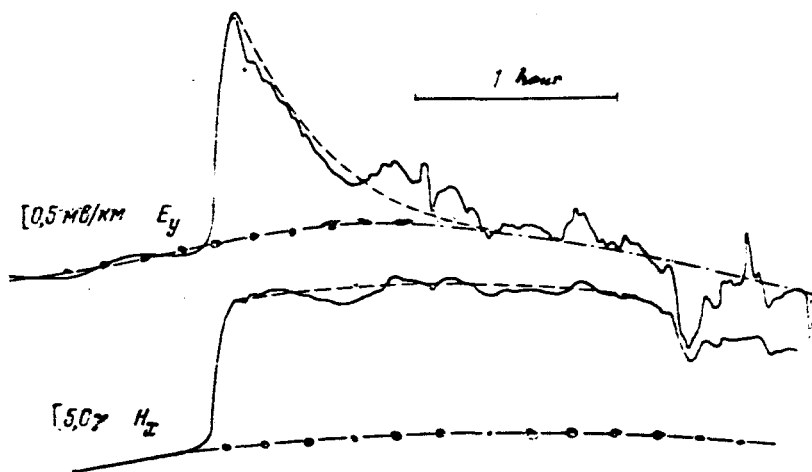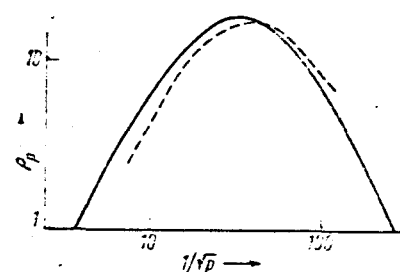

Fig.1   Fig.2

hours, the horizontal component of the electric field, E_y, settles in the course of one hour prior to its initial value.

As was shown in [4], the problem of sub-surface sounding with the utilization of nonstationary perturbations is resolved on the basis of

the transformation

$$F(p) = \int_0^\infty f(t)\, e^{-pt}\, dt, \qquad (1)$$

where p is a real number, having the frequency dimensionality, f(t) is dependence of the electric or magnetic field on time.

The apparent specific resistance of the profile is computed by the formula

$$\rho_p = \frac{0.4\pi}{p} \left[\frac{E_y(p)}{H_x(p)} \right]^2, \qquad (2)$$

where, as admitted in the m.t.s. method, E is expressed in millivolts per kilometer and H — in gammas, p_p — in ohm·m.

The integral transformations of the temporal dependences of H_x and E_y were computed by assortment of simple functions of the type

$$f_1(t) = 1 - \exp(-\alpha t), \quad f_2(t) = [1 - \exp[-\alpha t]] \exp(-\beta t). \quad (3)$$

For a chosen time scale, to factual registrations of $H_x(t)$ and $E_y(t)$ correspond in Fig. 1 the representations

$$H_x(t) = 1 - \exp(-20t), \qquad E_y(t) = [1 - \exp(-20t)] \exp(-3t), \quad (4)$$

denoted by dashes. For ρ_p we obtain

$$\rho_p = \frac{0.4\pi}{p} M \left[\frac{p(20 + p)}{(3 + p)(20 + p)} \right]^2, \qquad (5)$$

where M is the scale factor, determined by the concrete conditions of registration.

In Fig. 2 we plotted the curve of ρ_p in the bilogarithmic scale, according to formula (5). The dashes denote the curve obtained with the help of the quadratic formula (14) of the work [4] by ordinates, taken directly from the oscillogram.

Thus, from a single electromagnetic process a practically total depth sounding curve has been obtained. The initial stage of the establishment process in the region of great p, when the electric and magnetic fields vary abruptly, reflects the structure of the superficial portions of the Earth's crust, which are characterized by the aggregate longitudinal conductivity of the semidentary stratum S. At a later stage of the process there

is a significant level of magnetic field intensity, while the electric field practically settles to its original value which corresponds to the right-hand descending branch of the sounding curve. It is by this part of the curve for ρ_p that the depth $h_{\text{сум}}$ to the high conductivity layer is determi ed. By the abscissa of the intersection point $1/\sqrt{p_0}$ of the left-hand descending branch of the curve for ρ_p with the line $\rho_p = 1$ ohm.m we determine

$$S = 890 \frac{1}{\sqrt{p_0}}.$$

Within the bounds of method's precision the value S = 3500 mho coincides with the value of S obtained by the magneto-telluric survey at the same point. By the abscissa of the intersection point of the right-hand branc with the line $\rho_p = 1$ ohm·cm we determine

$$h_{\text{сум}} = \frac{1}{\sqrt{0,4\pi}} \frac{1}{\sqrt{p_0}} \approx 250 \text{ км.}$$

Note that when processing by the harmonic analysis method the descenaing branch of the curve p_k of analogous geoelectric profiles may be obtained only from the first harmonics of daily variations of the Earth's electromagnetic field. But when analyzing an iden-
tical storm with SC, the investigation of a temporal process of some 2-hour duration is sufficient for obtaining the required information.

Currently, the author, in col-
laboration with Z. G. Lomakina, works out a program for the computation of the transformation of F (p) with the help of an "EVTSM"-type computer. The results of analysis of bay-like perturb-

Fig. 3

ations with SC for the Pleshchenitsy Observatory (Minsk) coincide with those of N. V. Lipskaya [3]. The computed values of ρ_p as a function of $1/\sqrt{p}$ are plotted in Fig. 3.

The range of reliable values of p was estimated as a function of the choice of minimum time interval τ for various simplest functions.
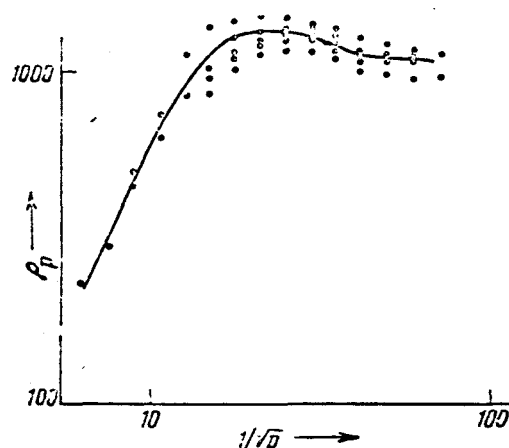
It was found that for the pulses really encountered we may practically postulate $p \geqslant 4/\tau$. This requirement is satisfied for all the above-described curves.

The estimates show that when interpreting the ground observations of magnetic storms with the view of m.t.s., it is possible to utilize within sufficiently broad range of values p the plane wave scheme, without taking into account the correction for the Earth's sphericity.

Therefore, the rich spectrum of the initial stage of magnetic storms with SC allows their recommendation for a widespread utilization during sub-surface magneto-telluric soundings.

*** T H E   E N D ***

R E F E R E N C E S

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